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Factors associated with periodontal diseases in Jordan: principal component and factor analysis approach

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Abstract: This study was conducted to identify factors associated with periodontal disease in a Jordanian population using principal component and factor analysis techniques. Subjects were 603 dentate patients aged 15-65 years attending dental teaching clinics at the Jordan University of Science and Technology. Their oral hygiene and periodontal status were assessed using plaque index, gingival index, probing pocket depth, clinical attachment level, gingival recession, and number of missing teeth. Factor and principal component analysis and binary logistic regression were conducted to identify factors related to periodontal disease. Probing pocket depth, clinical attachment level, gingival recession, and number of missing teeth were sorted as the same factor and could be combined in one scale to measure the severity of periodontal disease. On the other hand, plaque index and gingival index were sorted as another factor and could be combined in another scale to correlate between oral hygiene and gingival status. The results demonstrated that increased age, low level of education, increased plaque index score, not brushing teeth, smoking more than 15 pack-years, and having diabetes were significantly associated with increased severity of periodontal disease. In conclusion, it was possible to form a standard scale, based on linear combinations of periodontal indices and parameters, to measure the severity of periodontal disease and determine its risk indicators. (J. Oral Sci. 48, 77-84, 2006)

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Introduction

It is well known that severe forms of periodontal disease are clustered in the minority of individuals in a given population (1-3). Those high-risk individuals and the extent and severity of their periodontal problems should be identified and evaluated so that preventive measures and treatment procedures can be provided in a cost-effective manner. Researchers in the field of periodontology used to describe the presence, extent, and severity of periodontal diseases using many parameters and indices. However, the use of different periodontal parameters in the same study, ignoring the fact that some of these variables are inter-correlated and possibly measure the same construct, produces redundancy in those variables, which in mathematical terms causes linear dependence in the structure. Moreover, using these parameters separately would result in a great underestimation of cases, which tends to bias the results toward a null hypothesis, thus underestimating the impact of the explanatory variables on periodontitis. In an attempt to overcome these problems, Hotelling (4) used principal component analysis to reduce the observed variables into a smaller number of principal components or artificial variables that account for most of the variance in the observed variables. Linear combinations of these indices and measures can be formed using principal component and factor analysis to determine results simultaneously, instead of examining one or another separately. This study was therefore conducted to identify the factors associated with the severity of periodontal disease in a dental teaching clinic population in the north of Jordan using the principal component and factor analysis

techniques.

Materials and Methods

Patients attending to receive initial dental treatment at the teaching clinics of the Initial Treatment Unit, Faculty of Dentistry, Jordan University of Science and Technology, during the course of the investigation were included in this study. The series comprised 603 patients; 270 males and 333 females aged 15-65 years. Subjects were excluded from this study if they had a history of surgical periodontal treatment or traumatic or hyperplastic gingival disease, or if they were undergoing orthodontic treatment. The study was approved by the Human Research Committee of the Jordan University of Science and Technology.

Patients were interviewed using a special form to record the following data: age, gender, marital status, years of education, monthly income in Jordanian currency, tooth brushing habit (yes or no), use of auxiliary aids, and presence of any chronic disease. Frequency of brushing per day, type of auxiliary aid, number of cigarettes smoked per day, number of years of smoking, and type of chronic disease were also recorded when applicable.

Using the dental chair and kit allocated for treating the subjects, the oral hygiene of six selected teeth and the periodontal status of all teeth, excluding the third molars, were assessed using plaque index (PlI) as described by Silness and Löe (5), gingival index (GI) as described by Löe and Silness (6), probing pocket depth (PPD), clinical attachment level (CAL), gingival recession (GR), and number of missing teeth (MT). Sterile dental mirrors and explorers were used to assess plaque accumulation and gingival status while standardized Michigan O periodontal probes with Williams's markings (Diatech, Switzerland) were used to measure PPD, CAL, and GR. Probing pocket depth was measured from the gingival margin to the bottom of the crevice to the nearest millimeter (mm). In cases of exposure of the cement-enamel junction (CEJ), clinical attachment level was measured to the nearest mm by reading off the distance from the CEJ or the margin of fixed restoration to the base of the pocket, and in other cases indirectly by subtracting the distance from the gingival margin to the CEJ from the pocket depth. Gingival recession was measured to the nearest mm by reading off the distance from the CEJ to the gingival margin. The tip of the probe was used to feel for and determine the CEJ level. Four surfaces (mesio-facial, mid-facial, disto-facial, and mid-lingual) of six representative teeth were assessed and scored for plaque index. GI, PPD, CAL, and GR were measured at six sites (mesio-facial, mid-facial, disto-facial, mesio-lingual, mid-lingual and disto-lingual) per tooth for all teeth, excluding the third molars. Mean PlI, GI, PPD, CAL, and GR over all examined surfaces or sites were computed for each subject and used in principal component and factor analysis to find scales that measured the severity of the disease.

Sixty subjects were randomly selected and re-examined on two occasions on two subsequent days. To obtain PlI scores, 360 teeth and 1,440 surfaces were re-examined, and to obtain GI, PPD, CAL, and GR measurements, 1,496 teeth and 5,984 surfaces were re-examined. Of the total number of duplicate PlI and GI scores, 99.8% and 98.2%, respectively, fell within ± 1 of the original, and 95.4% and 94.1%, respectively, fell within the same score category (i.e., exact agreement). The percentage of duplicate PPD measurements that fell within ± 1 mm of the original was 98.9%, and that which matched the same depth category was 92.9%. Of the total number of duplicate CAL measurements, 97.3% fell within ± 1 mm of the original and 91.7% fell within the same measurement category. Regarding GR measurements, 99.7% fell within ± 1 mm of the original and 97.5% agreed exactly with the original measurement category.

For the purpose of the analysis, the following variables were categorized in the following manner.

Level of education and income: Years of education and income in Jordanian currency (JD) (1 U.S. dollar = 0.7 JD) were used as continuous variable in regression analysis. Education was categorized for descriptive purposes into three levels: zero to six years of education (primary education), seven to twelve years of education (secondary education), and more than twelve years of education (college or higher education). Income was categorized into three levels: 150 JD or less, 151-250 JD, and more than 250 JD.

Brushing of teeth and use of auxiliary aids: Patients were classified according to the frequency of brushing into the following categories: no brushing, brushing less than once a day on average, brushing once a day, and brushing more than once a day. The use of auxiliary aids like toothpicks, dental floss, and miswak (a stick obtained from a plant called Salvadore Persica used by Muslims as a natural toothbrush) was assessed in a dichotomous manner; i.e., use of such aids vs. no use. Patients answering affirmatively may therefore have used more than one type.

Smoking habit: History of smoking was recorded according to the number of cigarettes smoked per day and the number of years of smoking. Smoking was then quantified as a composite value of the number of packs of cigarettes smoked per day multiplied by the number of years smoked; i.e., the number of pack-years. Subjects were then stratified into three categories: non smoking, smoking 15 pack-years or less, and smoking more than 15 pack-

years.

Systemic diseases: The chronic diseases that were self-reported in this study were diabetes, hypertension, allergy, and peptic ulcers. The assessment was performed in a dichotomous manner; i.e. presence vs. absence of that chronic disease. Patients may have had more than one chronic disease.

Characteristics of subjects were described using frequency distributions and analyzed using chi-square tests. The dental characteristics and gingival and periodontal parameters of subjects according to age group were described by computing means and standard deviations and analyzed by analysis of variance (ANOVA). Factor and principal component analysis was conducted to find a standard scale to measure the severity of periodontal diseases. Input data were prepared for factor analysis by including variables that were believed to be related to each other in some way and that allowed sufficient observation to provide reliable estimation of correlations between the variables. The principal component method for factor extraction was chosen. The optimal number of factors to be extracted was determined using different guidelines including the Kaiser Criterion (7), percentage of variance accounted for, the Scree test (8), size of the residuals, and maximum likelihood methods. The varimax method was used in a rotation procedure to produce a matrix of factor loadings. Once all significant loadings were identified, an attempt was made to assign some meaning to the factors based on the patterns of the factor loadings. Considering all the variables' loading on a factor, including the size and sign of the loading, the determination was made as to what the underlying factor could represent. Factor scores that could quantify individual cases on a latent continuum using a z-score scale ranging from approximately -3.0 to +3.0 were estimated and used for further analysis. The outcome of interest, score, had a skewed distribution. Although ordinal logistic regression analysis using the ordinal nature of this health outcome was attempted, the proportional odds assumption, which is required for analysis of ordinal data, was violated. Therefore, binary logistic regression was conducted to find the variables that were associated with having a high score or severe condition. Z-scores falling in the highest tertile (higher than the 66.3th percentile) were defined as high severity scores. This cutoff point was selected because the proportional odds assumption was met only for scores that fell in the lowest and middle tertiles. The analyses reported in this study were performed using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), version 11.5. Comments regarding statistical significance refer to probabilities of less than 0.05.

Results

Description of the study group

The demographic and socioeconomic characteristics and oral hygiene practices of 603 patients (44.8% male and 55.2% female) involved in this study are presented in Table 1. The mean age was 39.4 years; 79% were married and 21% were single. The percentages of subjects who had completed primary, secondary or higher education were 26.5%, 38.0% and 35.5%, respectively.

Plaque, gingival, and periodontal parameters and indices for all subjects according to age groups are detailed in Table 2. The means of PlI and GI for all subjects were 1.27 and 1.17, respectively and those for PPD, CAL, and GR were 3.21 mm, 4.06 mm, and 0.91 mm, respectively. Mean MT was 3.56.

Principal component and factor analysis

Plaque and gingival indices were moderately correlated (Pearson's correlation coefficient = 0.716, $P < 0.005$) and both were weakly correlated with other periodontal parameters. Correlations between PlI and the other variables ranged from 0.175 to 0.473 and those between GI and the other variables ranged from 0.201 to 0.439. The other variables were moderately to highly inter-correlated amongst each other. It thus seems that two relatively independent factors, or components, were reflected in the correlation matrix, one related to oral hygiene and gingival status and the other to periodontal status. As depicted in Table 3, the first factor had significantly high loadings, or correlations, from four variables: PPD (0.697), CAL (0.896), GR (0.810), and MT (0.764). It is therefore reasonable to combine these variables in one scale which can be called the periodontal disease scale, and to employ this scale to measure the severity of periodontal disease. Scale reliability was assessed by calculating coefficient alpha. This was 0.79 (95% CI; 0.74, 0.83), indicating that this scale has adequate and acceptable reliability.

Scores using this scale were calculated for each individual using the following equation: periodontal disease severity score = - 0.152 * PlI - 0.165 * GI + 0.244 * PPD + 0.350 * CAL + 0.338 * GR + 0.395 * MT.

Subjects were then categorized into two groups according to periodontal disease severity scores: group 1 (low score, n = 402) and group 2 (high score, n = 201). Mean ± standard deviation of scores were -0.57 ± 0.39 for group 1 and 1.14 ± 0.86 for group 2.

Moreover, the second factor had high loadings from two variables i.e., average PlI (0.896) and GI (0.898). Hence, it was also reasonable to combine these variables in a scale that may reflect the causal relationship between plaque and gingivitis. However, this factor was ignored in

further analyses.

Factors associated with periodontal disease severity scores

After adjusting for the effect of other factors in the model, increased age, decreased years of education, increased PII, not brushing teeth, smoking more than 15 pack-years, and having diabetes were the only factors associated with increased periodontal disease severity score (Table 5). The odds of having high severity score increased by 14% for one year increase in age and by 54% for each unit increase in PII but they decreased by 6% for each additional year of education. The odds of having high severity score for those who brushed their teeth less than once a day and those who brushed their teeth once a day were 0.23 and 0.38 times the odds for people not brushing their teeth, respectively. For those who smoked more than 15 pack-years, the odds ratio of having high severity score was 3.44 compared to non smokers. On the other hand, the odds ratio for diabetics compared to non diabetics was 6.61.

Discussion

Principal component analysis has been used in psychological and other biometric applications but has rarely been applied in clinical settings. It was employed in this study in order to find a series of linear combinations of the original variables such that the variance extracted from the original variables by the new variables was as large as possible. The analysis demonstrated two statistically significant factors which accounted for about 74% of the variance. The first factor had significantly high loadings

Table 1 Distribution of study subjects by age and demographic, socioeconomic and oral hygiene variables

Category	Decade (age in years) 15-24 % (n)	25-34 % (n)	35-44 % (n)	45-54 % (n)	55-65 % (n)	% (Total)	*P*-value[c]
Gender							0.264
Male	42.6[a] (49)	38.9 (51)	50.0 (55)	42.6 (55)	50.8 (60)	44.8[b] (270)	
Female	57.4 (66)	61.1 (80)	50.0 (55)	57.4 (74)	49.2 (58)	55.2 (333)	
Marital status							< 0.05
Single	84.3 (97)	20.6 (27)	1.8 (2)	0.8 (1)	0.8 (1)	21.2 (128)	
Married	15.7 (18)	79.4 (104)	98.2 (108)	99.2 (128)	99.2 (117)	78.8 (475)	
Education							< 0.05
0-6 (primary)	1.7 (2)	4.6 (6)	13.6 (15)	43.4 (56)	68.7 (81)	26.5 (160)	
7-12 (secondary)	51.3 (59)	51.9 (68)	44.5 (49)	28.0 (36)	14.4 (17)	38.0 (229)	
> 12 (college or higher education)	47.0 (54)	34.5 (57)	41.9 (46)	28.6 (37)	16.9 (20)	35.5 (214)	
Income (JD)							< 0.05
≤ 150	22.6 (26)	25.2 (33)	25.4 (28)	38.0 (49)	67.8 (80)	35.8 (216)	
151-250	42.6 (49)	43.5 (57)	39.1 (43)	29.5 (38)	17.8 (21)	34.5 (208)	
> 250	34.8 (40)	31.3 (41)	35.5 (39)	32.5 (42)	14.4 (17)	29.7 (179)	
Brushing							< 0.05
No	14.9 (17)	14.5 (19)	3.6 (4)	30.2 (39)	50.0 (59)	22.9 (138)	
< once a day	19.4 (22)	32.8 (43)	41.0 (45)	38.8 (50)	32.2 (38)	33.0 (198)	
once a day	31.6 (36)	26.7 (35)	29.1 (32)	14.7 (19)	10.2 (12)	22.3 (134)	
> once a day	34.2 (39)	25.0 (34)	26.4 (29)	16.3 (21)	7.6 (9)	21.9 (132)	
Auxiliary aids							0.175
No	70.3 (83)	60.3 (79)	63.4 (71)	61.5 (80)	60.2 (71)	62.6 (384)	
Toothpicks	10.2 (12)	14.5 (19)	15.2 (17)	12.3 (16)	11.0 (13)	12.8 (77)	
Dental floss	11.0 (13)	7.6 (10)	6.1 (7)	13.8 (18)	12.7 (15)	10.4 (63)	
Miswak	8.5 (10)	17.6 (23)	15.2 (17)	12.4 (16)	16.1 (19)	14.2 (85)	

[a] Percentages are based on number of individuals within each age group

[b] Percentages are based on a total of 603 individuals

[c] Chi-square test

Table 2 Oral hygiene and periodontal characteristics of the study subjects by age (mean ± SD [a])

Variable[b]	Decade (age in years)					Total	*P*-value[c]
	15-24 n = 115	25-34 n = 131	35-44 n = 110	45-54 n = 129	55-65 n = 118	N = 603	
PlI	1.15 ± 0.75	1.23 ± 0.72	1.33 ± 0.76	1.21 ± 0.81	1.46 ± 0.90	1.27 ± 0.79	< 0.05
GI	1.11 ± 0.80	1.09 ± 0.80	1.17 ± 0.74	1.15 ± 0.77	1.36 ± 0.88	1.17 ± 0.80	0.075
PPD	2.48 ± 0.64	2.90 ± 0.87	3.01 ± 0.91	3.56 ± 1.04	4.05 ± 0.82	3.21 ± 1.02	< 0.05
CAL	2.50 ± 0.72	3.24 ± 1.44	3.70± 1.90	4.86 ± 2.88	5.94 ± 2.61	4.06 ± 2.22	< 0.05
GR	0.06 ± 0.19	0.42 ± 0.88	0.77 ± 0.21	1.36 ± 1.54	1.92 ± 2.26	0.91 ± 1.54	< 0.05
MT	0.71 ± 1.19	1.31 ± 2.39	2.17 ± 3.14	5.43 ± 4.97	8.10 ± 5.10	3.56 ± 4.62	< 0.05

[a] Standard deviation

[b] PlI: plaque index; GI: gingival index; PPD: probing pocket depth; CAL: clinical attachment level; GR: gingival recession; MT: missing teeth

[c] One-way analysis of variance

Table 3 Correlation coefficients between the periodontal parameters and the two factors extracted by principal component analysis after rotation using varimax method

Component	Oral hygiene and periodontal parameters					
	PlI	GI	PPD	CAL	GR	MT
I	0.199	0.174	0.697	0.896	0.810	0.764
II	0.896	0.898	0.379	0.355	0.245	-0.040

PlI: plaque index; GI: gingival index; PPD: probing pocket depth; CAL: clinical attachment level; GR: gingival recession; MT: missing teeth

from four variables; PPD, CAL, GR, and MT. The second factor had high loadings from two variables; PlI and GI. Factor I appeared to reflect "periodontal disease severity".

This study revealed that age was significantly associated with severity of periodontal disease, a finding consistent with other studies (9-12). The literature views the higher prevalence of periodontal destruction in the elderly as a reflection of a lifetime of disease accumulation rather than as an age-specific condition (13). However, it was hypothesized that the result could reflect true cohort effects (14). Lower level of education was significantly associated with increased severity of periodontal disease; this result is in agreement with the results of other studies (15-17). The association could be attributed to low awareness of oral hygiene standards and lack of motivation towards them. Plaque was significantly associated with periodontal disease severity, a finding consistent with many other studies (18,19). Results from well-controlled clinical studies have found the quantity of plaque to be weakly correlated with periodontitis (20-22). However, studies using qualitative measures of plaque pathogens have offered mixed results. While periodontal pathogens are essential for periodontal disease destruction, these pathogenic microorganisms alone are not sufficient to explain the differences observed in periodontal disease severity. Periodontitis is now seen as resulting from complex interplay of bacterial infection and host response, often modified by behavioral factors (23,24). Not brushing was significantly associated with increased severity of periodontal disease. These results support the fact that dental plaque is the primary etiologic agent in periodontal disease.

An association between smoking and periodontal disease has been considered for a number of years. In this study,

Table 4 Estimates of adjusted odds ratios (OR) of having a high score of periodontal disease severity compared with a low score and their 95% confidence intervals (CI)

Variable	OR	95% CI	*P*-value
Age	1.14	(1.11, 1.17)	< 0.05
Education	0.94	(0.90, 0.99)	< 0.05
Average plaque Index	1.54	(1.11, 2.14)	< 0.05
Brushing [a]			
< once a day	0.23	(0.12, 0.45)	< 0.05
once a day	0.38	(0.18, 0.78)	< 0.05
> once a day	0.77	(0.47, 1.24)	0.28
Smoking [b]			
≤ 15 pack-years	1.27	(0.74, 2.25)	0.33
> 15 pack-years	3.44	(1.56, 7.58)	< 0.05
Chronic disease [c]			
Peptic ulcer	2.74	(0.81, 8.90)	0.08
Hypertension	3.06	(0.90, 8.11)	0.07
Allergy	2.97	(0.87, 7.92)	0.08
Diabetes	6.61	(3.30, 13.23)	< 0.05

[a] Reference category = no brushing
[b] Reference category = no smoking
[c] Reference category = absence of chronic disease

it was evident that the severity scores of periodontal disease were significantly higher in subjects smoking more than 15 pack-years when compared with non-smokers. Smoking 15 pack-years or less was not significantly associated with severity of periodontal disease; a finding which could indicate that a certain tobacco dose and smoking duration must be exceeded before smoking exerts an effect on the periodontal apparatus. Increased periodontal disease severity among heavy smokers was consistent with some studies (25-29). Although the possible pathways have been explored for many years, the route by which smoking affects periodontal tissues remains unclear. It appears that tobacco acts on the host through two main mechanisms: on one hand, systematically altering the immune response by reducing the production of antibodies and decreasing the viability of lymphocytes (30,31). On the other hand, it acts locally through cytotoxic metabolites, liberated by the combustion of the cigarette, affecting fibroblasts of the periodontal membrane (32). Recent findings regarding the reduced bone mineral content in aging smokers compared to that in non-smokers and the greater degree of osteoporosis in post-menopausal female smokers (33), suggest that smoking accelerates the rate of alveolar bone breakdown in periodontitis. Therefore, smoking cessation must be part of professional practice.

This study demonstrated that diabetics had more severe periodontal disease than non-diabetics. This association persisted even after adjustment for age, sex, education, smoking habit, brushing, use of auxiliary aids, and PlI. This finding is in agreement with some studies (34-36) but in contradiction with others (37,38). Diabetes has been linked to increased susceptibility to periodontal disease through a number of hypotheses (39-41). It is most likely that several factors interact, such as altered polymorphnuclear cell function and derangement of inflammatory protein response coverage at the periodontium, resulting in a higher prevalence and severity of periodontitis. Other factors including alterations in diabetic defenses and a unique population of subgingival microflora in diabetics may play a role in the association between periodontal disease and diabetes. Recently Grossi and Genco (42) proposed a model for the biological association between periodontal disease and diabetes mellitus. They mentioned that both an "infection-mediated" pathway in the periodontium and state of insulin resistance amplify the classical pathway of diabetic connective tissue destruction.

In conclusion, it was possible to form a new standard scale, based on linear combinations of periodontal indices and parameters, to measure the severity of periodontal disease. Severity of periodontal disease was significantly

associated with increased age, decreased years of education, increased PlI, not brushing teeth, smoking more than 15 pack-years, and having diabetes. Because the available evidence shows that important risk factors for periodontal disease relate to poor oral hygiene, tobacco use, low education level, and diabetes mellitus, integrated preventive strategies based on the common risk factors approach are recommended for public health practice. Jordan needs to establish a surveillance system for measuring progress in the control of periodontal disease and promotion of oral health; approaches for the integration of oral disease prevention within the prevention of non-communicable chronic diseases should be designed and implemented.

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